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DOMESTIC PREPAREDNESS PROGRAM: TESTING OF M90-D1-C CHEMICAL WARFARE AGENT DETECTOR AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

Terri L. Longworth
Kwok Y. Ong
Jacob L. Barnhouse

ENGINEERING DIRECTORATE

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This report characterizes the chemical warfare (CW) agent detection potential of the commercially available M90-D1-C Chemical Agent Detector. These detectors were tested against HD, GB, and GA vapor at various conditions. This report is intended to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of these detectors.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command, Program Director for Domestic Preparedness. This work was started in May 1999 and completed in July 1999.

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DOMESTIC PREPAREDNESS PROGRAM: TESTING OF M90-D1-C CHEMICAL WARFARE AGENT DETECTOR AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state and local capabilities to respond to Nuclear, Biological and Chemical (NBC) terrorism incidents. Emergency responders who encounter a contaminated or potentially contaminated area must survey the area for the presence of toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the capability of the commonly used, commercially available detection devices. Under the Domestic Preparedness (DP) Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Design Evaluation Laboratory (DEL) at Aberdeen Proving Ground, Edgewood, Maryland, performed the detector testing. DEL is tasked with providing the necessary information to aid authorities in the selection of detection equipment applicable to their needs.

Several detectors were evaluated and reported during Phase 1 testing in 1998. Phase 2 testing in 1999 continues the evaluation of detectors including the MIRAN SapphIRe Portable Ambient Air Analyzer, MSA tubes, the APD2000, and the M90-D1-C Chemical Warfare Agent Detector.

2. OBJECTIVE

This report characterizes the CW agent detection potential of the commercially available M90-D1-C Chemical Warfare Agent Detector. It is intended to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of these detectors. This report is one of several reports on the Phase 2 evaluations of detectors conducted during 1999.

3. SCOPE

This evaluation attempts to characterize the CW agent vapor detection capability of the M90-D1-C detector. The agents used were Tabun (GA), Sarin (GB), and Mustard (HD). These were considered representative CW agents because they are believed to be the most likely threats. Test procedures followed those described in the Phase 1 Test Report[1]. The test concept was as follows:

The Chemical Agent Detection System, M90-D1-C, is a lightweight, man portable CW agent detector that weighs 15.7 pounds including the rechargeable battery pack. The detector operates on NiCd, Mg, or Li types of batteries or other 12 V DC power sources. It is an automatic warning device that responds to all relevant chemical warfare agents (nerve, blood, or blister) and can also be programmed for other types of compound vapor detection (e.g. chlorine, phosgene, etc.). When powered with a power supply, it operates continuously and no daily servicing is required.

The M90-D1-C Chemical Warfare Agent Detector employs advanced ion mobility spectrometry (IMS) detection techniques. The M90 detects and identifies CW agents based on ion mobility spectrometry. An irritant or CW agent in the air is drawn into the cell assembly where the molecules are ionized by an Americium radiation source. The ions are swept down the cell through an electric field created by a series of electrodes to produce an electronic signature. The M90 detector uses the "Advanced Signal Pattern Recognition Method" (ASPRM) to process and to identify the CW agent based on the generated ion mobility spectrum. Its IMS sensor is unique and differs from conventional IMS technology in that no cell membrane is used and thus "back flushing" of the cell is not required. Traditional IMS applications (e.g. APD2000) use cell membrane and back flushing to prevent cell overloading and improve clear down rates after exposure to "high" concentrations of contaminant.

The M90 detector also incorporates a semiconductor cell (SCCell) in addition to the ion mobility cell (IMCell) for its CW agent detection. This new, improved type of SCCell enables further enhancement of the agent detection capabilities of the M90-D1-C. Responses from the SCCell are combined with the responses from the IMCell to provide better agent identifications and interference rejections.

Similar to the earlier models of the M90-D1 detector, the M90-D1-C does not require an additional computer to function. However, coupling with a computer facilitates using the additional features of the detector. This detector can be adapted for other detection applications besides CW agents. Through the computer, the M90-D1-C detector can be programmed to detect additional compounds. The User Interface Program (UIP) allows such programming and assists in maintenance diagnostics. A computer is needed to conduct the built-in internal heat decontamination of the detector should it became grossly contaminated. The programmability of the detector allows easy detection optimization by an operator to meet mission requirements.

The M90-D1-C detector contains an interchangeable data library that can store up to sixty gas-class-teaching slots. The teachings are required for agent detection and identification. The detectors are taught to recognize different compound behaviors under different conditions. Each of the teachings occupies one slot. The detector's internal logic uses the combined IMCell and SCCell outputs to compare with the stored signature teachings. The detector will either trigger the alarm (if a vapor closely matches one of the teachings) or ignore the vapor response as an interference with a baseline update. Baseline updating is a way for the detector to compensate for potential baseline drifts.

containing the agent. Each detector was tested three times under each condition. The time that the detector was exposed to the agent vapor until it alarmed was recorded as the alarm time. In addition, times for clear down after the agent challenge were noted. This is the time required for the detector to stop alarming after the agent vapor flow ends.

The detectors were each tested with the agents GA, GB and HD at different concentration levels at ambient temperatures and low (<5%) relative humidity in an attempt to determine the minimum detectable level (MDL). The detectors were evaluated at relative humidity conditions of 50% and 90% at ambient temperatures. Testing at temperature extremes of -30°C for GA and GB, 0°C for HD, and +50°C for the three CW agents were also conducted to observe temperature and humidity effects. HD was only tested down to 0°C due to its physical property limitations. Although HD freezes at approximately +15°C, it has a volatility of 92 mg/ m^3 at 0°C that is considered potentially hazardous. It should be noted that 0°C is lower than the current JSOR that only requires HD detection down to +15°C.

4.4 AGENT VAPOR QUANTIFICATION

The generated agent vapor concentrations were analyzed independently and reported in mg/m^3. The vapor concentration was quantified by the manual sample collection methodology[4] using the Miniature Continuous Air Monitoring System (MINICAMS) manufactured by O. I. Analytical, Inc., Birmingham, Alabama. The MINICAMS is equipped with a flame photometric detector (FPD), and operated in phosphorus mode for the G agents and sulfur mode for HD. This system normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS inlet. Here the concentrated sample is periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification.

For manual sample collection, the PCT was removed from the MINICAMS during the sample cycle and connected to a measured suction source to draw the vapor sample from the agent generator. The PCT was then re-inserted into the MINICAMS for analysis. This "manual sample collection" procedure eliminates potential loss of sample through sampling lines and the inlet assembly in order to use the MINICAMS as an analytical instrument. The calibration of the MINICAMS is performed daily using the appropriate standards for the agent of interest.

4.5 FIELD INTERFERENCE TESTS

After the agent sensitivity tests, the units were tested outdoors in the presence of common potential interferents such as the vapors from gasoline, diesel fuel, jet propulsion fuel (JP8), kerosene, AFFF liquid (Aqueous Film Forming Foam used for fire fighting), household chlorine bleach and insect repellent. Vapor from a 10% HTH slurry (a chlorinating decontaminant for CW agents), engine exhausts, burning fuels and other burning materials were also tested.

The field tests were conducted outdoors at M-Field of the Edgewood Area of Aberdeen Proving Ground in July 1999. These were not laboratory tests but field experiments involving

5. RESULTS AND DISCUSSION

5.1 MINIMUM DETECTABLE LEVELS

The minimum detectable level (MDL) for the two M90-D1-C detectors (A and B) are shown in Table 1 for each agent at ambient temperatures and low relative humidity (<5% RH). To establish the MDL, the agent concentrations were lowered until the detector did not alarm. The MDL values were recorded at the CW agent concentration exposure that produced slow, 1-2 minutes, but consistent alarms for three trials. The MDL concentrations are expressed in mg/m^3 and the equivalent parts per million (ppm) values are shown. The current military requirements for CW agent detection (Joint Service Operational Requirements [JSOR] for CW agent sensitivity for point detection alarms), the Army's established values for Immediate Danger to Life or Health (IDLH), and the Airborne Exposure Limit (AEL) are also listed as references to compare the detector's performance.

When compared to the JSOR and IDLH values, the MDLs of the M90-D1-C units for the CW agents tested are all at least an order of magnitude lower. Lower MDL represents better detection sensitivity. Army regulation AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity. The M90-D1-C units would not detect at the AEL levels.

Table 1. Minimum Detectable Level (MDL) at Ambient Temperatures and Low Relative Humidity

AGENT	Concentration in milligrams per cubic meter, mg/m^3, With parts per million values in parenthesis (ppm)				
	Detector A	Detector B	JSOR*	IDLH**	AEL***
HD	0.033 (0.005)	0.22 (0.033)	2.0 (0.300)	N/A	0.003 (0.0005)
GA	0.010 (0.001)	0.010 (0.001)	0.1 (0.015)	0.2 (0.03)	0.0001 (0.000015)
GB	0.008 (0.001)	0.008 (0.001)	0.1 (0.017)	0.2 (0.03)	0.0001 (0.000017)

* Joint Service Operational Requirements for point sampling detectors.
** Immediate Danger to Life or Health values from AR 385-61 to determine level of CW protection. Personnel must wear full ensemble with SCBA for operations or full face piece respirator for escape.
*** Airborne Exposure Limit values from AR 385-61 to determine masking requirements. Personnel can operate for up to 8 hours unmasked.

5.2 TEMPERATURE AND HUMIDITY EFFECTS

Table 2 lists the respective responses of the M90-D1-C detectors at various test conditions. The tests were conducted at ambient temperatures and RH conditions of

Table 2. M90-D1-C Responses at Various Temperatures and RH Conditions (Continued)

AGENT	Average Temperature °C	Relative Humidity %RH	Concentration mg/m³	Concentration ppm	Detector A Reference Level Reading	Detector A Alarm Time Range (seconds)	Detector B Reference Level Reading	Detector B Alarm Time Range (seconds
GB	20	<5	**0.008**	0.001	Low	14-53	Low	29-51
GB	20	<5	**0.092**	0.016	Low	6-7	Low	5-6
GB	20	<5	**33.0**	5.70	Medium	5	Medium	5
GB	20	50	**0.140**	0.024	Low	5	Low	5-6
GB	20	>90	**0.070**	0.012	Low	7	Low	7
GB	-30	0	**0.060**	0.008	Low	15-16	Low	7-8
GB	50	0	**0.080**	0.015	Low	6-7	Low	5-6

* Replaced detector A with detector C for this trial because detector A was showing residual effects from the gross exposure of an experimental decontamination solution in another test program.

5.3 FIELD INTERFERENCE

The results of the detector "false alarms" during the interferent exposures are presented in Table 3. False alarms mean the detector alarmed in the absence of CW agent. The ambient temperature and relative humidity levels during these tests were in the range of 26-36°C and 53-91%RH, with gentle wind. Both detectors false alarmed (Blister High) to all diesel and kerosene vapor trials. Also, for all trials both units false alarmed (Nerve Low) to AFFF. The detectors also false alarmed one out of six trials for the revved gasoline engine exhaust (Blister Low) and the idle diesel engine exhaust (Nerve Low). The false alarm rates are calculated to 6 of 21 (28.5%) substances and 26 of 122 trials (21%).

Table 3. Field Interference Testing Summary

Interferent	M90-D1-C Detectors A and B, One-minute Interferent Exposures	
	Total Trials	Total False Alarms
Gasoline Exhaust, Idle	6	0
Gasoline Exhaust, Revved	6	1
Diesel Exhaust, Idle	6	1
Diesel Exhaust, Revved	6	0
Kerosene Vapor	6	6
Kerosene on Fire	6	0
JP8 Vapor	6	0
Burning JP8 Smoke	6	0
Burning Gasoline Smoke	6	0
Burning Diesel Smoke	6	0
AFFF Vapor	6	6
Insect Repellent	2	0

tested at the 1% concentration level while detector B alarmed for 7 of the 12 tests. The false alarm rates were less frequent at the 0.1% concentration level. Those substances that did not cause false alarms at the 1% level were not tested at the 0.1% level. Detectors A and B false alarmed for 50% of the interferents tested at 0.1% saturation. Diesel vapor results at the 0.1% level are included in this list, but they were obtained during the agent plus interference testing.

Table 5. Results of Laboratory Interference Tests without Agents

Interferent Only	Detector A Reference Levels				Detector B Reverence Levels			
	1%		0.1%		1%		0.1%	
AFFF	Nerve	Low	No Alarm		Nerve	Low	No Alarm	
Antifreeze	Nerve	Low	No Alarm		Nerve	Low	No Alarm	
Bleach	Nerve	Low	No Alarm		Nerve	Low	No Alarm	
Diesel	No Alarm		Nerve*	Low	No Alarm		Blister**	Low
Floor Wax	Nerve	Low	Nerve	Low	Nerve	Low	Nerve	Low
Gasoline	Blister	Low	No Alarm		No Alarm		Not Tested	
JP8	Nerve	Low	Blister	Low	Nerve	Low	Blister	Low
Spray 9	Nerve	Low	Nerve	Low	Nerve	Low	Nerve	Low
Toluene	No Alarm		Not Tested		No Alarm		Not Tested	
Vinegar	Blister	High	Blister	Low	Blood	Low	Blister	Low
Windex	Nerve	Low	Nerve	Low	No Alarm		Not Tested	
Ammonia	Blister	Medium	Not Tested		No Alarm		Not Tested	

* Interferent caused false alarm (Nerve Low) for one of the three trials.

** Interferent caused false alarm (Blister Low), therefore not agent tested.

6. CONCLUSIONS

The M90-D1-C detectors have demonstrated CW agent vapor detection for HD, GA and GB. The threshold sensitivity is better than the current JSOR military requirements for a point sampling alarm at all conditions tested.

Civilian first responders and HAZMAT personnel use Immediate Danger to Life or Health (IDLH) values to determine levels of protection selection during consequence management of an incident. Army Regulation (AR) 385-61 provides IDLH and AEL values for GA/GB, and an AEL value for HD. AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity. The M90-D1-C detectors were able to detect G agents to their IDLH values at all temperature and humidity conditions tested. However, the detectors are unable to detect to the AEL values for HD, GA or GB.

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